**UDC: 681.3** https://doi.org/10.15407/jai2024.01.031

**V. Yashchenko**
Institute Problems of Mathematical Machines and Systems of the NAS of Ukraine, Ukraine
Akademika Glushkova avenue, 40, Kiev, 03680
vitaly.yashchenko@gmail.com
http://orcid.org/ 0000-0001-9396-6581

# FROM McCULLOCH TO GPT - 4: STAGES OF DEVELOPMENT OF ARTIFICIAL INTELLIGENCE

**Abstract.** The article examines the history of the development of artificial intelligence (AI), starting from its first theoretical and practical steps and tracing the evolution to modern achievements. The article provides an overview of the key milestones, scientific discoveries and technological breakthroughs made in the field of AI. The most important figures, ideas and principles that influenced its development are also discussed. In the context of this development, various definitions of artificial intelligence are given. There are several key stages in the history of AI: the early stages, the quiet period, the AI renaissance, and the era of AI in the new millennium. Each of these stages made its own unique contribution to the progress of AI. The modern period is characterized by rapid development, especially in the field of machine learning and deep learning. These methods allow artificial intelligence to learn from data and identify complex patterns. Advances in natural language processing, such as models GPT and its modifications, have shown outstanding results. However, despite linguistic advances, GPT remains limited in aspects important to creating strong AI. The article discusses the limitations of modern language models, as well as the prerequisites and prospects for the development of strong artificial intelligence. Special attention is paid to the project of Elon Musk, who, having launched the company X.AI, is engaged in research in the field of creating strong AI with the goal of "knowledge of reality." The article also proposes an alternative approach to creating strong artificial intelligence - the development of an artificial brain based on a multidimensional multi-connected receptor-effector neuron-like growing network. Some aspects of the emergence of artificial consciousness are also considered.

**Keywords:** artificial intelligence, strong artificial intelligence, neural-like growing networks, artificial brain.

**В. О. Ященко**
Інститут проблем математичних машин та систем НАН України, Україна
пр. Академіка Глушкова, 40, м.Київ, 03680
vitaly.yashchenko@gmail.com
http://orcid.org/ 0000-0001-9396-6581

# ВІД McCULLOCH ДО GPT - 4: ЕТАПИ РОЗВИТКУ ШТУЧНОГО ІНТЕЛЕКТУ

**Анотація.** У статті розглядається історія розвитку штучного інтелекту (AI), починаючи з його перших теоретичних і практичних кроків і досліджуючи еволюцію до сучасних досягнень. В статті представлений огляд ключових етапів, наукових відкриттів і технологічних процесів, зроблених в області AI. Також розглядаються найважливіші фігури, ідеї та принципи, що вплинули на його розвиток. В контексті цього розвитку наведені різні визначення штучного інтелекту. В історії AI виділяють кілька ключових етапів: ранні етапи, період затишшя, ренесанс AI і епоха AI в новому тисячолітті. Кожен із цих етапів несе свій унікальний вклад у прогрес AI. Сучасний період характеризується стрімким розвитком, особливо в області машинного навчання та глибокого навчання. Ці методи за допомогою штучного інтелекту навчаються на основі даних і виявляють складні закономірності. Продовження спостерігається в обробці природної мови. Такі моделі як GPT та його модифікації продемонстрували видатні результати. Тим не менше, незважаючи на лінгвістичні успіхи, GPT залишається обмеженим в аспектах, важливих для створення сильного AI. У статті розглядаються обмеження сучасних мовних моделей, а також пропозиції та перспективи розвитку сильного штучного інтелекту. Окрема увага приділяється проєкту Ілона Маска, який, запустивши компанію X.AI, займається дослідженнями в області створення сильного AI з метою «пізнання реальності». У статті також запропонований альтернативний підхід до створення сильного штучного інтелекту - розробка штучного мозку на основі багатомірної багатозв'язкової рецепторно-ефекторної нейроподібної розташовуючої мережі. Також розглянуті деякі аспекти виникнення штучного пізнання.

**Ключові слова:** штучний інтелект, сильний штучний інтелект, нейроподібні зростаючі мережі, штучний мозок.

## 1. Introduction

The development of artificial intelligence (AI) is an ongoing and evolutionary process, encompassing a wide range of scientific and technological advances. The ideas and concepts underlying AI originated long before its formal emergence as a scientific discipline, and more and more innovations have been made over time.

The history of artificial intelligence began about 70 years ago, but humanity has been moving in this direction for thousands of years. The interest in animating the inanimate was present in myths, legends, literature, and in practice. One of the directions that led to the development of artificial intelligence is the formalization of thinking and the attempt to translate it into the language of mathematics, understandable for computers. Another important direction is the development of computing machines, which eventually evolved into modern computers.

Ideas of transferring human abilities to inanimate objects appeared thousands of years ago in the form of automata and robot-like mechanical beings. Some examples of such automata include automaton dolls, golems, and the bronze giant Talas. Examples of artificial intelligence can also be found in the form of sacred statues and mechanisms created in Ancient Egypt and Ancient Greece. Other attempts to create artificial humans include the laboratory-style homunculi described by alchemists and the idea of an artificial human, which is reflected in Mary Shelley's Frankenstein.

While myths and legends raised questions about the formalization of thinking, mathematicians and philosophers were engaged in rigorous description of how thinking works and what rules to use. This became key to the development of the logic of artificial intelligence. Some of the early milestones in this field include Euclid's axioms in geometry, Aristotle's description of logic, and the basics of algebra from Al-Khwarizmi. Later, in physics, there was the idea of the world working as a big mechanism that follows logical laws. And for such a mechanical description of the world, mathematics was chosen.

Mathematician and philosopher Thomas Hobbes, as well as mathematicians Gottfried Leibniz and George Boole, proposed various methods and languages to describe thinking rigorously. In particular, Boole and Leibniz significantly developed mathematical logic, proposing formal languages for processing information and deriving new results. These languages became the basis for the development of artificial intelligence. Thus, the history of artificial intelligence stretches over many centuries, starting with the development of ideas in formalization of thinking and mathematical logic, and ending with the creation of modern computers, where artificial intelligence is implemented. However, to fully understand what is happening in the field of artificial intelligence, it is necessary to pay attention to the essence of AI itself, its origin and future development. These questions play an important role in our understanding of where humanity is headed. Now comes the point where it's worth asking questions about what artificial intelligence really is.

## 2. What is artificial intelligence?

Even to such a simple question, the answer is multifaceted. It is a science and a field of computer science that studies methods of computerized solutions to problems traditionally solved by humans. It is also a technology where machines with intelligence, such as robots, unmanned cars or other technical systems, are programmed to think and learn. Artificial intelligence is the ability of a computer to mimic human intelligence.

The definition of AI can be defined in many different ways, and many meaningful definitions have been proposed throughout history. This paper will examine several of these definitions in the context of the development of artificial intelligence.

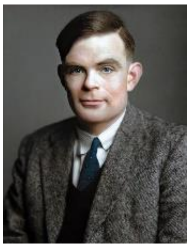

Fig. 1. A.Turing

Alan Turing's definition (1950): Alan Turing, one of the founders of the scientific field of AI, proposed a famous definition in his article "Computation and Intelligence".

He proposed the possibility of defining AI through the Turing test: if a machine is capable

of producing intelligent behavior indistinguishable from human behavior, then it can be said to possess intelligence. This definition emphasizes the external manifestations of intelligence and is based on the program's ability to behave as if it possessed thoughts and intelligence [1].

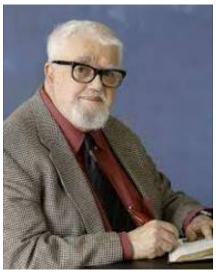

Fig. 2. J. McCarthy

Definition by John McCarthy (1956): John McCarthy, one of the founders of AI, defined AI as "the science and engineering of creating intelligent machines". He set out to create machines that could think, learn, and have the ability to improve themselves. This definition emphasises the desire to create machines with different intellectual abilities, and the engineering approach to achieving this goal.

Fig. 3. A.Shevchenko

Based on the results of discussion of this topic, Ukrainian scientists under the leadership of Doctor of Technical Sciences, Professor A. Shevchenko formulated domestic definitions of artificial intelligence (2022):

"Artificial intelligence is a function of artificial consciousness represented by the system of algorithms created and controlled by it, which provides self-learning according to the available information, acquired knowledge, rules, laws of society and its experience, creating on this basis new knowledge to fulfil human assignments, as well as the ability to carry out self-diagnosis and justify its decisions"[2].

The definitions given here reflect different aspects and approaches to understanding this field. Turing's definition emphasises the external manifestations of intelligence, and McCarthy's describes the scientific and engineering components of creating intelligent machines. All of these definitions are linked by a key idea - the presence of human intelligence in a non-human entity such as a computer. Definitions of AI continue to evolve with advances in the field and push us towards increasingly complex and intelligent systems capable of performing tasks that require human intelligence and knowledge.

### 3. Key stages of AI development

There are several key stages in the history of AI development, each with its own significance and contribution to AI progress. Among them we can distinguish the early stages, the period of quiescence, the AI renaissance and the AI era in the new millennium. Each of these stages has its own characteristic and is accompanied by unique achievements and progress.

The early stages of AI development include the birth and research of the first artificial neural networks that mimic the workings of the nervous system. Important achievements of this period were the McCulloch-Pitts model, which showed the possibility of modeling neural activity, and Alan Turing's proposal of a test to determine the intelligence of a machine.

The lull period is characterized by a relative slowdown in AI progress. However, it was during this period that the basis for further research was formed, namely, the emergence of the idea of expert systems - logical systems based on formal rules and knowledge bases.

The AI Renaissance was the period of a new round of AI development. During this period, machine learning methods, neural networks and expert systems were actively used. Major advances include the development of deep neural networks, which became the basis for image processing models, speech recognition, and much more.

In the AI era of the new millennium, AI has become an integral part of our daily lives. The application of AI has spread to many industries, including automotive, medical and financial. This period has seen explosive growth in data and computing power, enabling the application of deep learning techniques and the development of autonomous systems. Each of these phases has its own significant development milestones, achievements and prospects. They epitomise the constant progress of AI and the strengthening of its role in our modern world. As technology advances

and algorithms continually improve, AI continues to conquer new frontiers and open up new opportunities for us.

**3.1 Early stages of AI development (1943-1955)**

In 1943, in the journal Bulletin of Mathematical Biophysics, American neuropsychologist, neurophysiologist and theorist of artificial neural networks Warren McCulloch and American neurolinguistics, logician and mathematician Walter Pitts published the paper "A Logical Calculus of the Ideas Immanent in Nervous Activity", which became an important milestone in the development of research on artificial neural networks.

Fig. 4. W. McCulloch

Fig. 5. W. Pitts

McCulloch and Pitts presented a mathematical model of an artificial neuron. This was the first attempt to create a simplified mathematical model that mimicked the basic principles of neurons in the human brain. This model laid the foundation for neural networks, which are one of the main approaches to artificial intelligence.

McCulloch and Pitts' research is a precursor to modern research on artificial neural networks. However, it is worth noting that in the 1940s, computer resources were limited and practical application of their ideas was difficult at that time [3].

In 1949, Canadian psychologist Donald Hebb proposed an important principle that became known as Hebb's learning rule. This rule provided a theoretical framework for understanding how neural networks can learn from the interactions between neurons. Hebb developed this rule in his book The Organization of Behavior: A Neuropsychological Theory, which was published in 1949.

Hebb was one of the first to develop a theory of the relationship between the brain and thought processes. The scientist investigated the relationship of learning processes with the processes occurring in the structure of the brain's neural connections. According to Hebb, as a result of frequent stimulation of the nervous system, coordinated neural structures - cell assemblies - are formed.

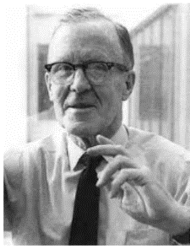

Fig. 6. D. Hebb

The essence of Hebb's rule can be expressed as follows: "When the axon of one neuron frequently and steadily excites another neuron, the efficiency of this neuron in excitation of the second neuron improves". In other words, if neurons are activated simultaneously, the synaptic connection between them is strengthened. This rule provides an intuitive explanation of the learning mechanism in neural networks: when a signal passes through a connection between two neurons, and this happens frequently, the strength of the connection between them increases. Thus, neurons that are activated together begin to make stronger connections, which facilitates learning of the network. Hebbian learning is a form of data-driven learning, and it is relevant in the context of forming connections between neurons in the brain. However, in the context of artificial neural networks, Hebb's rule has become a core principle of learning. It supports the idea that neurons that activate synchronously should have strengthened connections, which forms the pathway for learning machine learning algorithms and artificial neural networks.

In 1950, Alan Turing, a famous mathematician, logician, cryptographer, and one of the founders of the theory of computation, introduced the idea of a test to determine the intelligence of a machine in his article entitled "Computing Machinery and Intelligence". This test was proposed as a way to determine whether a machine has artificial intelligence, whether it is capable of carrying on a conversation in such a way that it could not be distinguished from a conversation with a human.

The idea behind the Turing Test included the following basic elements: A human, a machine, and a judge. The test is conducted using a "neutral" terminal through which the human and machine interact. The terminal

provides a text interface for communication; The judge interacts with the participants (human and machine) through the terminal. The task of the judge is to determine which of the participants is human and which is machine; The participants are allowed to ask any questions or have a free conversation. The machine must produce answers that are indistinguishable from human answers.

Turing believed that if a machine is able to conduct a conversation in such a way that the judge cannot distinguish which of the participants is a human and which is a machine, then it can be considered that this machine has intelligence. In his article, Turing suggested questions that could be used for testing and reasoned that the questions should be wide-ranging to include different aspects of intelligence.

The Turing Test has become one of the key moments in the history of artificial intelligence, and it has been extensively discussed and used in various fields. Subsequently, many researchers and engineers have endeavoured to create machines that pass the Turing Test, although opinion now varies as to its effectiveness and adequacy as a measure of artificial intelligence.

In 1956, a historic conference was held at Dartmouth College (USA), which is considered to be the "birth" of artificial intelligence. The conference was attended by leading scientists and researchers such as John McCarthy, Marvin Minsky, Allen Newell, Herbert Simon and others. The purpose of the conference was to discuss research directions related to building machines that can mimic human intelligence. Many of the key ideas and concepts discussed at this conference became the basis for the development of AI in the following decades. Conference participants put forward the idea that machines could be used to simulate human thinking and solve complex problems. This was the starting point for creating systems capable of performing tasks that were previously considered the prerogative of humans. During the conference, the first programs and research projects were proposed, such as building computers that play chess and developing a programming language for symbolic computation. Scientists discussed ideas such as logical inference, symbolic knowledge representation, and machine learning, which have become key research directions in artificial intelligence.

This conference played a crucial role in establishing AI as a research field in its own right. Although it took much longer to realize some of the goals of that time, the ideas expressed at the conference formed the foundation for the development of artificial intelligence in the following decades.

### 3.2 The Quiet Period (1956-1980)

The lull period (1956-1980) in the development of artificial intelligence was characterized by a reduced rate of progress and a relative slowdown in research in this field.

In the initial period of AI development, there were high expectations and hopes for the rapid achievement of full-fledged artificial intelligence. However, the realization of these expectations proved to be much more difficult than anticipated.

Limited resources, both computational and financial, were one of the reasons for the protracted period of AI development. At that time, computers had limited processing power and memory capacity. This made it difficult to solve complex problems and required additional resources for AI research.

The complexity of the problem and limited understanding of how human intelligence works was also an obstacle at this stage. Researchers realized that creating such a "universal intelligent machine" was proving to be much more difficult than anticipated. Understanding the processes underlying thinking and intellectual activity was insufficient to develop a full-fledged AI.

In addition, in 1969, Marvin Minsky and Seymour Peipert published the book "Perceptrons", in which they showed that the perceptron was not capable of solving some simple problems, such as the logic function XOR. The limitations stated in the book caused pessimism about the capabilities of neural networks, and this led to a decline in interest and investment in this area of research. The period associated with this book has been characterized as the "lull in the development of artificial intelligence" or the "winter of artificial intelligence". Funding for neural network projects declined and researchers

turned their attention to other machine learning techniques. Instead of developing a universal intelligence machine, researchers began to focus on solving narrow problems and using specialized methods. This period saw the development of expert systems - logical systems based on formal rules and knowledge bases that can make decisions or dialog in specific domains. Expert systems began to be used in medicine, finance, and other fields that required complex problem solving and informed decision making.

The lull period in AI development was still significant because it encouraged researchers to explore more specific aspects of AI and develop specialized systems. In addition, the limitations and complexities faced by researchers during that period also served as a basis for more careful and fundamental research in the latter period.

### 3.3 The AI Renaissance (1980-2000)

The period from 1980 to 2000 can be characterised as the "Renaissance of Artificial Intelligence" as significant advances in AI occurred during this time, leading to a resurgence of interest in the field after several decades of relative quiescence. Important developments and trends in the AI Renaissance include: Expert Systems - Expert systems began to be actively developed during this period. Expert systems were programmes that used the knowledge of experts in a particular field to make decisions. Examples include MYCIN (for diagnosing infectious diseases) and Dendral (for chemical analysis); Logic programming - programmers began to actively use logic-based programming languages, such as Prolog, to create expert systems and solve AI problems; Machine Learning - there was an increased interest in machine learning techniques, including those involving neural networks. Although neural networks of this time were much smaller and less efficient than modern networks, their research made important contributions to the field; Specialized programming languages - specialized programming languages, such as LISP and Prolog, emerged and were used to provide tools for more efficient implementation of artificial intelligence; Natural language processing programs - natural language processing programs were developed, although they were far from modern systems. This included systems for speech analysis and synthesis as well as text processing; Algorithm Optimization - research focused on optimizing algorithms and methods for solving AI problems.

The AI Renaissance represents an important stage in the history of artificial intelligence, where the foundations of many modern methods and technologies were laid. During this time, there was a new surge of interest and investment in AI research and development, which led to further development of the field in the following decades.

### 3.4 AI in the new millennium (2000-present)

Since the beginning of the new millennium, artificial intelligence (AI) has continued its rapid development, leading to significant changes in technological, scientific and societal terms. This period has seen key breakthroughs and advancements that have made AI an integral part of our daily lives.

The use of AI has become more and more widespread in various industries. The concepts of Big Data (Big Data) and its integration have promoted the use of data to learn and improve AI models.

The integration of AI with Internet of Things devices has led to the development of smart homes, smart cities, and control systems. Autonomous systems, robots, and autonomous vehicles equipped with AI have become a reality. The application of AI in augmented reality (AR) and virtual reality (VR) has opened new opportunities in education, healthcare, and entertainment industries.

However, along with progress have come new ethical and social issues surrounding the use of AI. Transparency, accountability, and data protection have become important aspects. The increased use of AI has also led to new advances in natural language processing, data clustering, and teacherless learning.

Research in quantum computing and its application in AI is opening up possibilities for faster and more efficient computing. Reinforcement learning is becoming

increasingly popular in the gaming industry and robotics, enabling the development of autonomous and intelligent.

In general, the modern period is characterized by the rapid development of artificial intelligence, which positively influences a wide range of technologies and leads to new breakthroughs. The application of AI in various industries continues to transform our reality and opens new horizons for future development.

One of the major trends in the development of AI has been machine learning and deep learning. These techniques have enabled AI to learn from data and find complex patterns and patterns. New multi-layer artificial neural network algorithms have led to significant performance improvements in areas such as pattern recognition, natural language processing, and computer vision. Advances in natural language processing and language models such as BERT and GPT show outstanding performance in natural language processing tasks. GPT (Generative Pre-trained Transformer) is a deep learning model that has demonstrated impressive results in natural language processing. GPT was first introduced by OpenAI in 2018. This model has been trained on large amounts of text data from the web and is capable of generating text based on prior context. The main advantage of GPT is its ability to model the next word or phrase based on the previous text. GPT utilizes a transformer architecture that consists of multiple interacting layers of self-referential attention and full-link layers.

Transformer attention allows the model to take into account long-range dependencies in the text and set appropriate weights for each word in context. This makes the model more flexible and able to generate high-quality texts. GPT has shown outstanding performance in tasks requiring natural language understanding and generation. It is able to fill in missing words in sentences, answer questions, translate texts into different languages, and even generate high-quality and coherent texts based on a small initial sentence or question.

In general, the effect of GPT and other language models lies in their ability to generate high-quality and coherent text based on prior context. They are important advances in natural language processing and move us closer to smarter and more natural communication systems.

However, despite the impressive results of GPT and other language models, they also face a number of limitations and challenges. For example, it is difficult to control and guarantee the accuracy of the generated text, especially when negative and obscene data needs to be processed. In addition, large computational resources and time are required to train and utilize such models.

## 4. limitations of GPT and other modern language models

We have reviewed the stages of AI development. We have shown impressive results of GPT and other language models. Nevertheless, despite the fact that GPT fully satisfies the Turing test and even surpasses it (because when communicating with GPT you feel that you are communicating with a person much smarter than an ordinary person) it is not a strong AI.

GPT and similar language models have demonstrated impressive results in natural language processing tasks, earning recognition for their ability to generate high quality and coherent text based on contextual cues. However, it is important to note that while GPT passes the Turing test and may even appear to be more intelligent than a very intelligent human, it does not possess strong artificial intelligence. This is due to certain limitations inherent in models such as GPT.

One of the key limitations of GPT and other language models is its lack of contextual understanding. While it can generate convincingly written text, it lacks a deep understanding of context. The model works by predicting the next word or phrase based on previous text, relying mainly on statistical patterns rather than a true understanding of the content.

In addition, GPT lacks self-awareness and purposefulness. He does not have his own goals, desires, or experiences. Rather, his work is based on processing data and patterns rather than truly comprehending and perceiving the world.

These language models are not capable of experiential learning. Unlike humans, they

cannot adapt to new information or change their behavior based on experience.

Moreover, GPT lacks emotional intelligence. It lacks the ability to understand or respond to emotions in texts and interact with users on an emotional level.

GPT and similar models also face problems related to uncertainty and reliability. The outputs generated may be context dependent and responses may be incorrect or illogical without sufficient information.

It is important to note that GPT lacks a comprehensive understanding of the world. It relies solely on what it has been taught - textual data - and lacks direct experience or perception of the physical world.

Bias and lack of objectivity are also pertinent problems. GPT can retain and propagate biases present in its training data, potentially leading to unwanted and biased responses, making it less suitable for making objective and informed decisions.

Thus, despite its remarkable linguistic capabilities and ability to generate coherent text, GPT remains limited in aspects considered critical for strong AI, such as comprehension, consciousness, experience-based learning, and emotional intelligence. It serves as a sophisticated text generation tool, but does not embody a complete and general artificial intelligence.

## 5. Prospects for Building Strong AI

Artificial intelligence continues to evolve every year, with impressive results. As we have already noted, this has been particularly evident in the creation of language models such as GPT. However, while GPT passes the Turing test and is able to communicate with humans at a high level, it is still not strong AI. Strong Artificial Intelligence (SAI) is a form of artificial intelligence that has the ability to solve problems that require human intelligence. Strong AI differs from existing AI systems, such as highly specialised algorithms and machine learning, in that it is capable of independent thought, decision-making and consciousness. Strong AI is an autonomous system capable of independently accumulating knowledge about the external world, learning from its experience and the behaviour of its peers, adapting to external conditions and making decisions without human assistance.

Some scientists believe that it is necessary to improve machine learning algorithms and develop new methods of data processing to create an SII. Others believe that it is necessary to develop fundamentally new neural network technology with self-awareness and purposefulness, similar to the biological neural network that makes up the human brain. For example, Ilon Musk, a well-known entrepreneur and engineer, has launched a new company called X.Al, which is launching an artificial intelligence endeavor with the goal of "learning about reality." In a statement, X.Al said their main goal is to develop research on "deep learning math" and "theory of everything" for large neural networks, as well as finding answers to humanity's basic questions and understanding the nature of the universe. The company, consisting of 12 experts in computer science including artificial intelligence, aims to create new technologies with self-awareness and purpose [4]. The X.Al team includes former top experts from Google and Microsoft. X.AI is actively seeking specialists and collaborating with other companies in Musk's "empire" including Tesla and Twitter [5]. Ilon Musk also predicts that superintelligent artificial intelligence will be developed within five or six years and will surpass human capabilities.

The "Improving Machine Learning Algorithms and Data Processing" point of view implies that it is possible to achieve SII by gradually improving existing machine learning algorithms and data processing methods. Advances in this direction include research in deep learning, neural networks, optimization algorithms, and statistical data processing. However, this approach may face the limitations of current methods and require large computational resources.

The development of I. Musk's new technology involves research on "deep learning math" and "theory of everything" for large neural networks, i.e. actually improving deep learning technology.

There is also another approach - creation of a fundamentally new technology, development of a new type of artificial neural

networks, maximally similar to biological neural networks, which have all the functions belonging to biological neural networks. An example of such technology is the Multidimensional Multi-connected Receptor-Effector Neural-like Growing Networks (mmrenGN) developed at the Institute of Problems of Mathematical Machines and Systems of the National Academy of Sciences of Ukraine.

## 6. Multidimensional multiconnected receptor-effector neural-like growing networks

MmrenGN are a new type of neural networks. Models of these networks have shown the possibility of multilevel storage and processing of large volumes of concepts, images, events or situations in various spatial representations such as tactile, visual, acoustic, gustatory, through compression of information at each level, as well as multilevel control of actuators of robots or autonomous mobile intelligent systems. MmrenGNs are created on the basis of analysis of scientific ideas reflecting regularities in the structure and functioning of biological structures of the human brain.

### 6.1 Biological structure of the human brain

The human brain consists of two hemispheres - left and right, each of which has its own functions and is subdivided into four

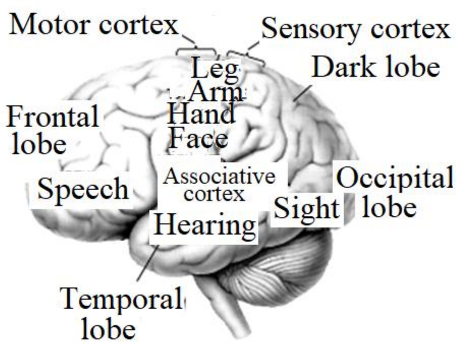


Fig. 7. The structure of the brain

lobes Fig.7.

The frontal lobe is located in the front part of the brain. It is responsible for higher mental functions such as planning, problem solving, and decision making. The frontal lobe also contains centres responsible for personality, behaviour, emotions. This area also controls speaking and writing, as well as body movements. The parietal lobe is located in the upper part of the brain. It is responsible for interpreting speech and perceiving sounds. Information about touch, pain, and temperature is processed in this area. Also located in the parietal lobe are centres responsible for spatial and visual perception and memory.

The occipital lobe is located in the back upper part of the brain. It is responsible for processing visual information. The occipital lobe contains areas that process signals from vision, hearing, motor and sensory information, and is also responsible for memory.

The temporal lobe is located in the lower part of the brain. It is responsible for understanding language and speech, as well as sequencing and organising actions. These four main lobes of the brain work together, interacting with each other to ensure the

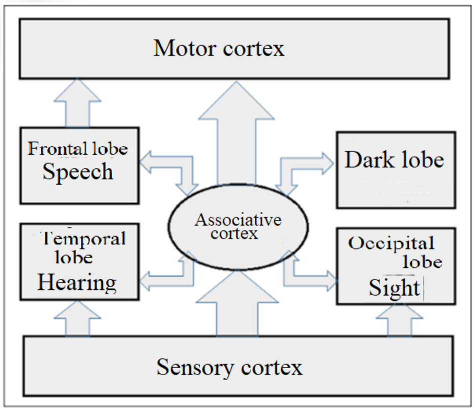


Fig. 8. Simplified functional diagram of the brain

normal functioning of various aspects of mental and physical activity. Figure 8 shows a simplified functional diagram of the brain.

### 6.2 Structure of a Multidimensional multiconnected receptor-effector neural-like growing networks

Multidimensional multiconnected receptor-effector neural-like growing networks (mmren-GN), using various spatial representations of information, perceive, memorize, and process descriptions of images of objects or situations in a problem area and

also generate control actions on the external environment.

Multidimensional multiconnected receptor-effector neural-like growing networks is a set of interconnected two-way

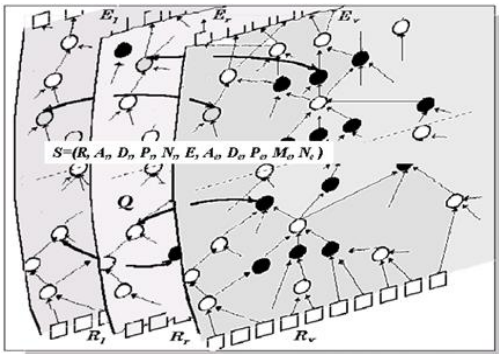

Fig. 9. Topological structure of mmrenGN

acyclic graphs that describe the state of an object and the actions it generates in various information spaces.

The topological structure of mmren-GN is represented by a graph (Fig.9). Formally, mmren-GN are given as follows

$$S = (R, A_r, D_r, P_r, M_r, N_r, E, A_e, D_e, P_e, M_e, N_e)$$

with $R \supset R_v, R_s, R_t; A_r \supset A_v, A_s, A_t; D_r \square\ D_v, D_s, D_t; P_r \supset P_v, P_s, P_t; M_r \supset M_v, M_s, M_t; N_r \supset N_v, N_s, N_t; E \supset E_r, E_{d1}, E_{d2}; A_e \supset A_r, A_{d1}, A_{d2}; D_e \supset D_r, D_{d1}, D_{d2}; P_e \supset P_r, P_{d1}, P_{d2}; M_e \supset M_r, M_{d1}, M_{d2}; N_e \supset N_r,$

$N_{d1}, N_{d2};$ and where $R_v$, $R_s$, and $R_t$ is a finite subset of receptors, $A_v$, $A_s$, and $A_t$ is a finite subset of neuron-like elements, $D_v$, $D_s$, and $D_t$ is a finite subset of arcs, $Pv$, $Ps$, and $Pt$ is a finite set of excitation thresholds of neuron-like elements of the receptor zone, belonging, for example, to visual, auditory, and tactile information spaces, $N$ is a finite set of variable connectivity coefficients of the receptor zone, $E_r$, $E_{d1}$, and $E_{d2}$ is a finite subset of effectors, $A_r$, $A_{d1}$, and $A_{d2}$ is a finite subset of neuron-like elements, $D_r$, $D_{d1}$, and $D_{d2}$ is a finite subset of effector arcs zones $P_r$, $P_{d1}$, and $P_{d2}$ is a finite set of excitation thresholds of neuron-like elements of the effector zone, belonging, for example, to the speech information space and action space, **N** is a finite set of variable connectivity coefficients of the effector zone.

Thus, in mmren-GN information about the external world, its objects, their states and situations describing the relationship between them, as well as information about the actions caused by these states, is stored due to its reflection in the network structure, and the arrival of new information causes the formation of new associative nodes and links and their redistribution between the nodes that have arisen earlier, while the common parts of these descriptions and actions are identified, which are automatically generalized and classified.

### 6.3 Structure of the artificial brain based on mmren-GN

A simplified scheme of the artificial brain based on mmren-GN, presented in Figure 10, includes several main areas and structures. First of all, at the beginning of the artificial

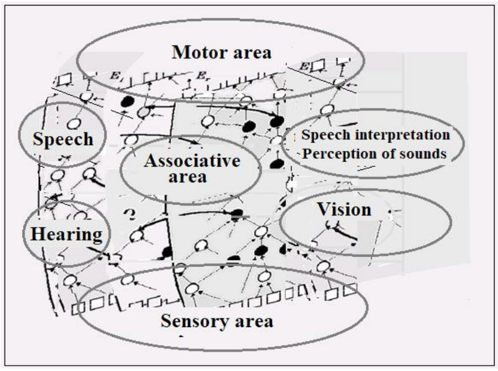


Fig. 10. Simplified scheme of the artificial brain in the structure of mmren-GN

brain functioning process, a sensory region is formed in mmren-GN. In this area, sensory neural ensembles, with the help of appropriate devices and sensors, perceive and process information from sources of sound, vision, tactile sensations, temperature, etc.

The sensory area consists of receptors that respond to various attributes and characteristics of objects and concepts. Further, at the first level of the sensory domain, neural ensembles are formed that contain overlapping parts of descriptions of specific concepts. For example, this level may include ensembles of neurons describing parts of the human body, such as leg, hand, arm, face, torso, etc. The second level includes more general concepts, such as a description of a person as a whole.

In the process of information perception and learning, associative area and related structures are generated, which are responsible

for hearing, speech, interpretation and understanding of speech, personality formation, behaviour and emotions. Based on the received information and accumulated knowledge, ensembles of active neurons are formed, which are responsible for action planning, decision making, problem solving and organising behaviour. Thus, an artificial brain based on mmren-GN is a system including sensory area, associative structures and ensembles of active neurons, which interact to process and analyse information, plan and implement actions.

This structure of mmren-GN makes it possible to form meanings as objects and connections between them as the information is perceived and the network itself is built. In this case, each sense (concept) acquires a separate component of the network as a vertex connected with other vertices. In general, this corresponds quite well to the structure reflected in the brain, where each explicit concept is represented by a particular structure and has its denoting symbol. The network is practically free from restrictions on the number of neuron-like elements in which to place the corresponding information, i.e. to build the network itself representing the given subject area. Besides, the network acquires increased semantic clarity due to the formation of not only connections between neuro-like elements, but also the elements themselves as such, i.e. here there is not just the construction of a network by placing semantic structures in the environment of neuro-like elements, but, in fact, the creation of this environment itself, as the equivalent of the memory environment. Thus, neural-like growing networks appear to be a convenient apparatus for modeling the mechanisms of purposeful thinking as a performance of certain psychophysiological functions.

In neural-like growing networks information is stored as a consequence of its reflection in the network structure. Multidimensional neural-like growing networks are represented by a multilevel, multidimensional structure reflecting the structure of the described classes of objects. Information about objects and their classes is represented by ensembles of associatively interconnected vertices distributed over the network structure. The input of new information into the network causes the process of building its structure (redistribution of connections between existing and newly appearing vertices) with simultaneous excitation of neuro-like elements. As a result of this process, the described object is included into the class to which it belongs or a new class of objects is formed. This is how classification and selection of common features of objects is performed. The algorithm of network construction automatically establishes associative links between object descriptions by their common features. The description of an object or a class of objects is localized in some part of the network, which allows to efficiently perform various associative search operations. Economical representation of information in n-GN is realized due to compression of information at each of its levels, as well as due to the fact that identical combinations of features of several objects are represented by one common subset of network vertices.

Network training is carried out simultaneously with its construction in accordance with the rules of network construction and operation.

An important property of mmren-GN is the ability to form control actions on the external environment (i.e., to train the network to produce control signals in the effector zone), in accordance with the knowledge acquired by the network as a result of accumulation, analysis, classification and generalization of information from the external world (i.e., information processing in the receptor zone of mmren-GN). In the case of hardware realization of mmren-GN, this property becomes even more important (especially in the construction of robotic systems) due to the possibility of parallel reception of information on the receptor field from the perceiving organs, propagation and issuance of control actions to the external world.

Although these networks are still in the research phase, they have the potential to be utilized in the development of strong AI.

However, it is important to note that the development of strong AI is a complex and ongoing process. it involves many different areas of study, including computer science,

mathematics, neurobiology, and philosophy [6, 7].

### 6.4 Toward the question of consciousness in AI systems

Consciousness in artificial intelligence is a complex and fascinating concept that has captured the attention of researchers, scientists, philosophers, and the public. As AI continues to evolve, the question arises: Is the emergence of consciousness in AI systems possible and can machines achieve a level of consciousness comparable to human consciousness?

Consciousness in biological systems such as humans refers to awareness of sensory (vision, hearing, taste, touch, and smell) and psychological (thoughts, emotions, desires, and beliefs) processes. However, the subtleties and intricacies of consciousness make it a complex, multifaceted concept that remains enigmatic despite exhaustive research in neurobiology, philosophy, and psychology. Consciousness in biological systems such as humans is related to the operation of the nervous system and the functioning of the brain.

The possibility of the emergence of consciousness in AI systems. To date, artificial intelligence has demonstrated remarkable success in tasks such as image classification, natural language processing, and speech recognition. However, AI models do not possess consciousness. They have no subjective experience, self-awareness, or understanding of context beyond what they have been trained to process. They lack the depth that human consciousness has. Nevertheless, researchers are trying to bring AI closer to the human mind.

Consciousness is a complex and multifaceted phenomenon, and there are many theories that attempt to explain its nature. Dualism, materialism, functionalism, phenomenology, emergent theory, idealism, two-dimensional theory, and Eastern philosophies offer different approaches to understanding consciousness. Dualism holds that consciousness and the physical body exist separately. Materialism links consciousness to physical processes in the brain. Functionalism emphasises the functions and roles of consciousness. Phenomenological theory is based on subjective experiences. Emergent theory considers consciousness to be an emergent property of complex neural networks. Idealism asserts that consciousness is the underlying reality. Two-dimensional theory combines materialism and idealism. Eastern philosophies explore different concepts of consciousness related to reincarnation, karma, and enlightenment. Each of these theories contributes to the field of consciousness studies.

It is suggested that the basis for achieving AI consciousness can be provided by theoretical frameworks such as integrated information theory (IIT), global workspace theory (GWT) and general artificial intelligence (AGI). Integrated information theory, proposed by Giulio Tononi, argues that systems capable of integrating information at a high level can be considered conscious. Current artificial intelligence models are becoming increasingly sophisticated and capable of processing large amounts of information, which may contribute to the development of consciousness [8].

Global workspace theory developed by Bernard J. Baars. In his concept, Baars argues that consciousness is a shared space for the exchange of information between independent cognitive modules. He proposes that consciousness is like a theatre where information is broadcast to a "global workspace". This suggests that an AI equipped with such a workspace could have some form of consciousness. This theory quickly gained popularity in cognitive science and is still one of the dominant theories of consciousness today [9].

It should also be noted that the development of general artificial intelligence, which has the ability to understand, learn and apply knowledge to solve a variety of tasks, is considered as one of the necessary conditions for the manifestation of consciousness in artificial intelligence.

At the moment, despite impressive results in machine learning and deep learning, the realization of consciousness in artificial intelligence remains elusive. The notion of consciousness involves complex interactions between multiple neurons and networks that

process information and generate ensembles of activity in the brain.

It is expected that by integrating an mmren-RS-based artificial brain into an android robot, providing it with the ability to learn, communicate, learn by example, embed itself in its environment and perhaps one day it will be discovered that the robot behaves like a human and is aware of itself as a person. This would imply the emergence of consciousness. For now, however, this prospect remains hypothetical and requires further research, development and testing. Questions related to the nature and possibilities of consciousness in artificial intelligence remain open.

## 7. Conclusions

This article reviews the history and development of artificial intelligence (AI) from McCulloch to GPT-4. The focus is on the modern period, where the exponential growth of AI development, especially in machine learning and deep learning, has played an important role. Machine learning models such as GPT and its subsequent versions have made significant advances in natural language processing. The paper also points out the limitations of current language models in aspects important for creating artificial intelligence comparable to human intelligence. This implies the need for further development and research in this area.

The article touches on the issue of artificial consciousness and discusses Integrated Information Theory and Global Workspace Theory. IIT argues that systems capable of integrating information at a high level can be considered conscious. GWT offers a different approach, believing that consciousness is represented as a global workspace, integrating information from different modalities and modules. The article also draws attention to the prospects for strong artificial intelligence and the project of Ilon Musk's X.AI company, focusing on researching and building strong AI and "reality cognition". An alternative approach related to the creation of an artificial brain is represented by a new type of neural network - a multidimensional multi-connected receptor-effector neural-like growing network.

As conclusions, it should be noted that despite significant advances in AI development, the creation of strong AI and consciousness is still a major challenge due to the shortcomings of existing technologies. The key requirement at this stage is to develop a fundamentally new approach and technology. An alternative approach, such as creating an artificial brain, offers a new effective direction for creating a strong artificial intelligence that can surpass human intelligence in the future.

## Література

1. Alan Turing, «Computing Machinery and Intelligence», Mind, vol. LIX, no. 236, October 1950, pp. 433 - 460.

2. Shevchenko, A. ets. «Strategy for Artificial Intelligence Development in Ukraine»: monograph /DOI: 10.15407/ development_strategy_2023.

3. McCulloch, W. S.; Pitts, W. (1943), "A logical calculus of ideas immanent to nervous activity", Bulletin of Mathematical Biophysics, 5 (4): 115-127, doi: 10.1007 / BF02478259.

4. AIR FORCE. Elon Musk is getting into the artificial intelligence game. His new company X.Al starts work on AI. https://www.bbc.com/russian/articles/ce4zlnlylpjo.

5. Musk has launched a new startup, X.AI, to develop artificial intelligence. https://techno.nv.ua/innovations/mask-zapustil-startap-dlya-razrabotki-bezopasnogo-iskusstvennogo-intellekta-50338632.html.

6. Vitaliy Yashchenko Neural-like Growing Networks the Artificial Intelligence Basic Structure. SAI 2014: Intelligent Systems in Science and Information 2014 pp 41–55. https://link.springer.com/chapter/10.1007/978-3-319-14654-6_3.

7. Vitaliy Yashchenko Multidimensional Neural-Like Growing Networks - A New Type of Neural Network. DOI: 10.14569/IJACSA.2015.060401 https://thesai.org/Publications/ViewPaper?Volume=6&Issue=4&Code=IJACSA&SerialNo=1.

8. Tononi, Giulio (2008). "Consciousness as Integrated Information: A Provisional Manifesto". The Biological Bulletin. 215 (3): 216 - 242. doi:10.2307/25470707. PMID 19098144.

9. B. J. Baars (2005). Global workspace theory of consciousness: toward a cognitive neuroscience of human experience Progress in brain research 150, 45-53.

## References

1. Alan Turing, "Computing Machinery and Intelligence," Mind, vol. LIX, no. 236, October 1950, pp. 433-460.

2. Shevchenko, A. ets. «Strategy for Artificial Intelligence Development in Ukraine: monograph».

DOI: 10.15407/development _strategy_2023.

3. McCulloch, WS; Pitts, W. (1943), "A logical calculus of ideas immanent to nervous activity", Bulletin of Mathematical Biophysics, 5 (4): 115-127, doi: 10.1007 / BF02478259.

4. AIR FORCE. Elon Musk is getting into the artificial intelligence game. His new company X.Al starts work on AI. https://www.bbc.com/russian/articles/ce4zlnlylpjo.

5. Musk has launched a new startup, X.AI, to develop artificial intelligence. https://techno.nv.ua/innovations/mask-zapustil-startap-dlya-razrabotki-bezopasnogo-iskusstvennogo-intellekta-50338632.html.

6. Vitaliy Yashchenko. Neural-like Growing Networks the Artificial Intelligence Basic Structure. SAI 2014: Intelligent Systems in Science and Information 2014 pp 41-55. https://link.springer.com/chapter/10.1007/978-3-319-14654-6_3.

7. Vitaliy Yashchenko. Multidimensional Neural-Like Growing Networks - A New Type of Neural Network. DOI:10.14569/IJACSA.2015.060401 https://thesai.org/Publications/ViewPaper?Volume=6&Issue=4&Code=IJACSA&SerialNo=1.

8. Tononi, Giulio (2008). "Consciousness as Integrated Information: A Provisional Manifesto". The Biological Bulletin. 215 (3): 216-242. doi:10.2307/25470707. PMID 19098144.

9. B. J. Baars (2005). Global workspace theory of consciousness: toward a cognitive neuroscience.

The article has been sent to the editors 07.02.24.
After processing 26.02.24.
Submitted for printing 20.03.24